PROGRESS REPORT ON NASA/EPA JOINT PROGRAM
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MICROBIAL FILTERS AND HIGHER PLANTS FOR TREATING HAZARDOUS AND TOXIC CHEMICALS

BY:

B. C. WOLVERTON, PH.D.

AND

REBECCA C. McDONALD

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
NATIONAL SPACE TECHNOLOGY LABORATORIES
NSTL, MS 39529

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INTRODUCTION

In our first progress report (February, 1983), the microbial filters with and without vascular plants were evaluated for their ability to degrade organophosphorus pesticides. This second group of experiments used a plant-free microbial rock filter and one with reeds (*Phragmites communis*) to degrade and/or absorb a selection of carcinogenic organic solvents and organochlorine pesticides.

Benzene and its derivatives are among the highest volume-of-use organic solvents in industry today. They are found in the production and/or use of such products as rubber, paint, paint removers, resins, styrene, dry-cleaning fluids, leather, waterproof fabrics, linoleum, explosives, pharmaceuticals, and photographic chemicals.

This group of organics primarily affects the blood-forming bone marrow. It is suspected of causing cancers such as acute leukemias and lymphosarcomas. Chromosomal aberrations may follow toxic exposures. Latent effects in humans from exposure may occur 6 to 14 years later.

This report contains data from potable water and domestic wastewater contaminated with benzene, p-xylene (p - dimethylbenzene), and toluene (methyl-benzene).

In addition, the degradation of two organochlorine pesticides - lindane and chlordane - was studied under similar conditions.

DESCRIPTION OF EXPERIMENTAL SYSTEMS

Each system consists of two components in series. The first component is a plastic, covered reservoir with 133-ℓ capacity which was used to retain

the raw sewage for 24 h in order to deplete the dissolved oxygen and produce an anaerobic media. The second component is a galvanized steel trough filled to a depth of 16 cm with railroad rocks 2.5-7.5 cm in diameter and to a depth of 5 cm with pea gravel 0.25-1.3 cm in diameter. Each trough measured 50.5 cm W x 30.5 cm D x 298 L. Two troughs were used in this segment of the program. One was plant-free, and the other contained reed (*Phragmites communis*). Each trough is drained and sampled via a bottom valve.

An experimental run consists of filling each plastic reservoir with either tap water or raw sewage from NSTL Lagoon #1. If raw sewage were used, the suspended solids were allowed to settle out over a 24 h period and the solution to go anaerobic. After 24 h with the sewage experiments or immediately following their being filled with tap water, either the organic solvents or pesticides were added and the solutions mixed. Initial samples were collected and the solutions transferred to the troughs. Samples were removed from each trough within 0.1 h (6 min) of introduction and at 3, 6, and 24 h intervals.

ANALYTICAL PROCEDURE

A sample of the sewage or tap water before introduction of the organic solvents or pesticides was analyzed for pH, total suspended solids (TSS), total dissolved solids (TDS), total phosphorus (TP), total kjeldahl nitrogen (TKN), and 5-day biochemical oxygen demand (BOD_5), according to *Standard Methods for the Examination of Water and Wastewater*, 14th Edition. The total organic carbon (TOC) and total carbon (TC) were determined using a Beckman 915 B Tocamaster.

The organic solvents monitored in this study were determined using a Tekmar LSC-2 Liquid Sample Concentrator and a Hewlett-Packard 5880A Gas Chromatograph with the following conditions:

A. Purge and trap conditions:

Purge time	12 min
Purge gas	N_2
Purge flow rate	40 mℓ/min
Desorb temp	190°C
Desorb time	4 min

B. Gas chromatograph conditions:

Column	6' x 1/4" OD glass, Chrom W, 100-120 mesh, 1.95% OV 270/1.5% OV 17
Oven temperature program	50°C - Initial temp @ 2 min, 10°/min - Program rate 115°C - Final temp
Carrier	N_2, 30 mℓ/min
Detector	FID (250°C)

The retention times from initiation of the desorb mode for benzene, toluene and p-xylene were 1.40, 2.31, and 4.50 min, respectively. The solvents' concentrations were calculated by comparing the area counts against those of aqueous standards made each day and analyzed under the same conditions.

The pesticides were extracted from aqueous solutions into isooctane using a Baker-10 extraction system and C_{18} disposable columns. Each disposable column was washed prior to extraction with methanol followed by deionized, distilled water.

The extracted solution was analyzed with a Hewlett-Packard 5880A Gas Chromatograph using the following conditions:

Column	6' x 1/4" glass, Chrom W, 100-120 mesh, 1.95% OV 210/1.5% OV 17
Injector temperature	200°C
Oven temperature	190°C, isothermal
Carrier	N_2, 40 mℓ/min
Injection volume	1.0 µl
Detector	Ni-63 Electron Capture (330°C)

The retention times for lindane and chlordane were 2.43 and 6.5/min, respectively. The concentrations were calculated in the same manner as outlined above.

RESULTS

The water quality profile of the tap water and domestic wastewater used in these experiments can be found in Table 1. The wastewater provides more nutrients and available carbon for enhanced microbial activity and reed growth.

The organic solvent data is presented in Table 2. A comparison of the data for benzene can be readily seen in Figure 1. With starting concentrations of approximately 10 mg/ℓ in tap water, a microbial filter/reed system can reduce benzene down to trace levels, 0.005 mg/ℓ, within 24 h. A plant-free system is much less efficient. When the aqueous media contains high concentrations of available carbon such as in wastewater, the rate of benzene removal is much slower.

The plant roots enhance the initial sorption rate by increasing available surface area. The microbial filters with reeds sorbed approximately 24% more benzene initially than the plant-free microbial filters. This effect was the same with tap water and domestic wastewater.

The toluene and p-xylene data are presented in Figures 2 and 3, respectively. The difference between plant-free and reed systems was not nearly as great as in the study with benzene. The initial sorption effect was only 15% higher with plants than without plants. The increase in molecular weight without appreciable change in polarity is one possible explanation for the slower response of the plants. Future studies will address this issue.

The lindane and chlordane data can be found in Table 3 and Figure 4. The initial concentrations in domestic wastewater averaged 5.6 and 6.6 mg/ℓ for lindane and chlordane, respectively. Lindane was more readily sorbed

in the filters than chlordane. Both were degraded and/or sorbed more efficiently in the reed systems to concentrations of 0.440 and 0.139 mg/ℓ for lindane and chlordane, respectively. This is an equivalent reduction of 92% and 98%, lindane and chlordane, respectively.

Overall, these sets of data indicate that a microbial filter's efficiency is improved with the growth of reeds. A system such as this also can reduce the concentration of carbon-based compounds more efficiently when carbon from other sources is minimized.

Table 1. Mean water quality profile of the tap water and domestic wastewater (prior to settling) used in this study.

Parameter	Conc., mg/ℓ	
	Tap Water	Domestic Wastewater
pH (std. units)	7.7	6.4
Total suspended solids	<1.0	29
Total dissolved solids	235	282
Total kjeldahl nitrogen	3.3	15.4
Total phosphorus	2.1	3.5
5-day biochemical oxygen demand	<1.0	60.3
Total organic carbon	4.4	36.1
Total carbon	44.9	91.0

Table 2. Mean organic solvent concentration as a function of exposure time in the filters.

Organic	Solution	System	No. Replicates	Concentration, mg/ℓ				
				0 h	<0.1 h	3 h	6 h	24 h
Benzene	tap water	w/o reed	8	10.66	4.50	2.67	2.24	1.13
		w/reed	8	9.33	1.70	0.95	0.39	0.05
	domestic wastewater	w/o reed	10	10.69	4.27	2.85	2.65	1.59
		w/reed	11	9.59	1.49	0.84	0.60	0.23
Toluene (methylbenzene)	tap water	w/o reed	14	7.48	2.50	0.54	0.25	0.042
		w/reed	15	6.60	1.30	0.78	0.22	0.005
	domestic wastewater	w/o reed	13	6.95	2.11	0.92	0.80	0.26
		w/reed	14	7.13	1.11	0.66	0.49	0.12
p-Xylene (p-dimethyl-benzene)	tap water	w/o reed	12	3.98	1.55	0.30	0.20	0.09
		w/reed	12	4.07	0.84	0.65	0.43	0.14
	domestic wastewater	w/o reed	11	4.45	1.63	0.68	0.70	0.46
		w/reed	13	4.34	0.98	0.69	0.65	0.35

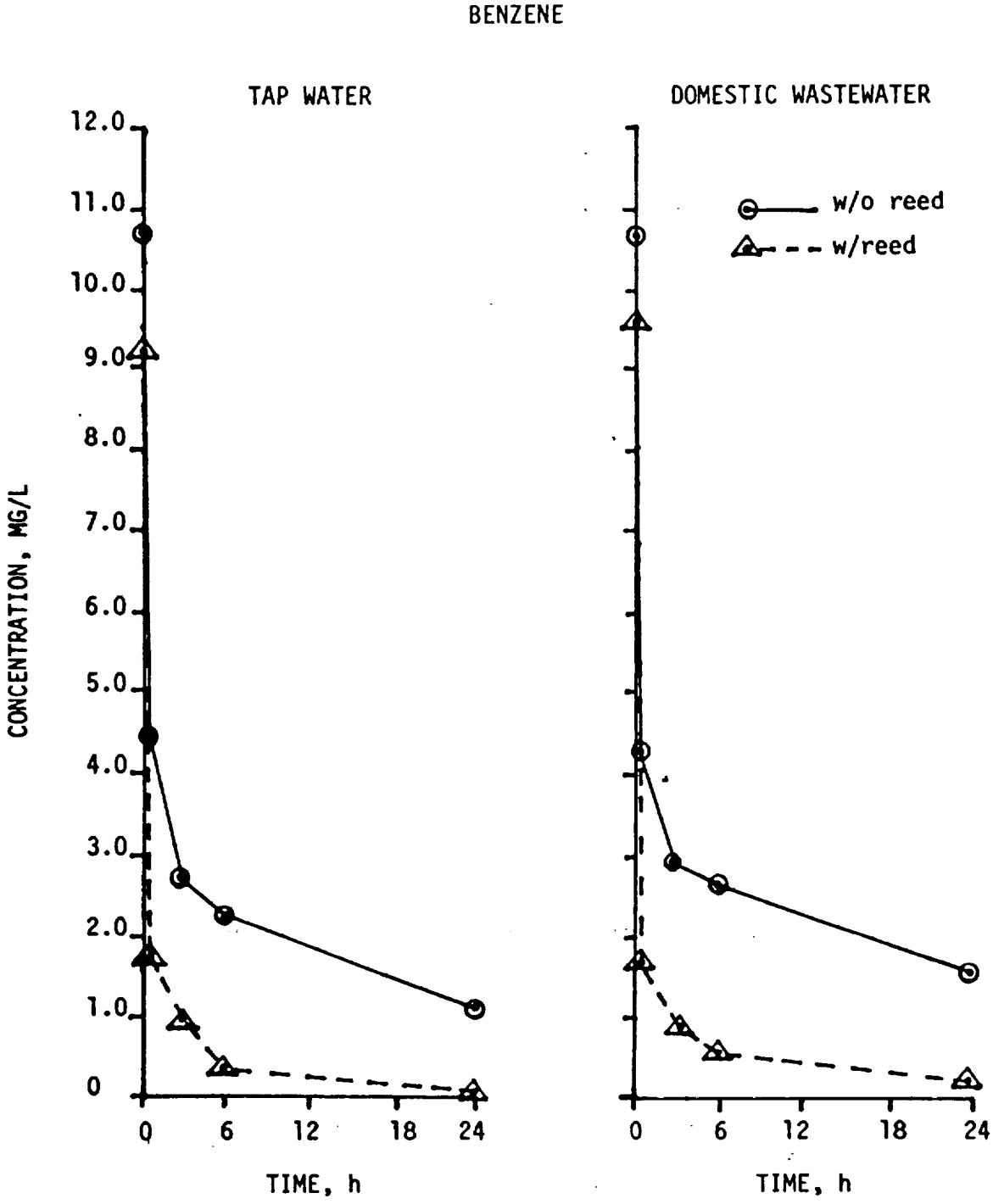

Figure 1. Removal of benzene from tap water and domestic wastewater as a function of filter exposure time.

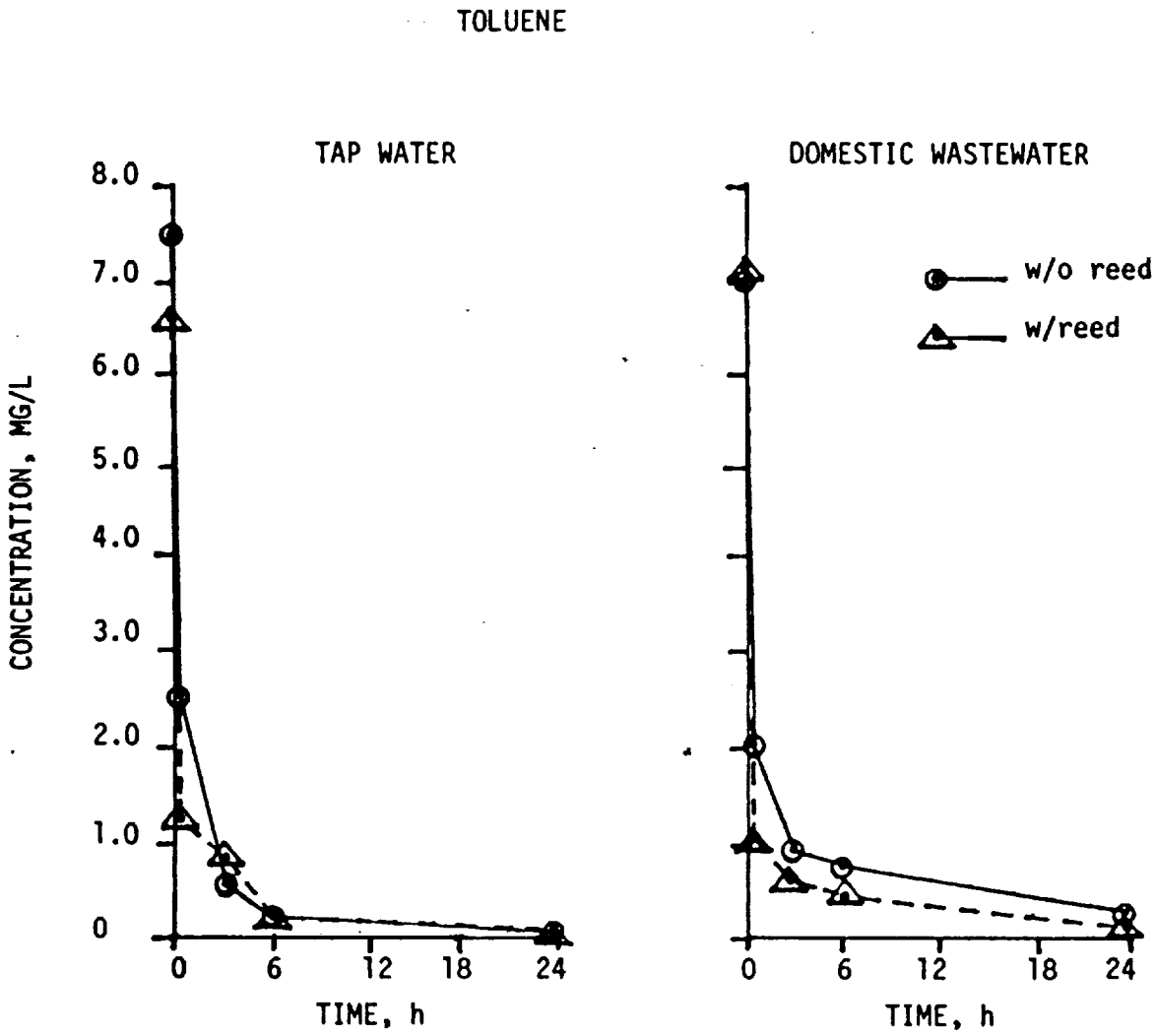

Figure 2. Removal of toluene from tap water and domestic wastewater as a function of filter exposure time.

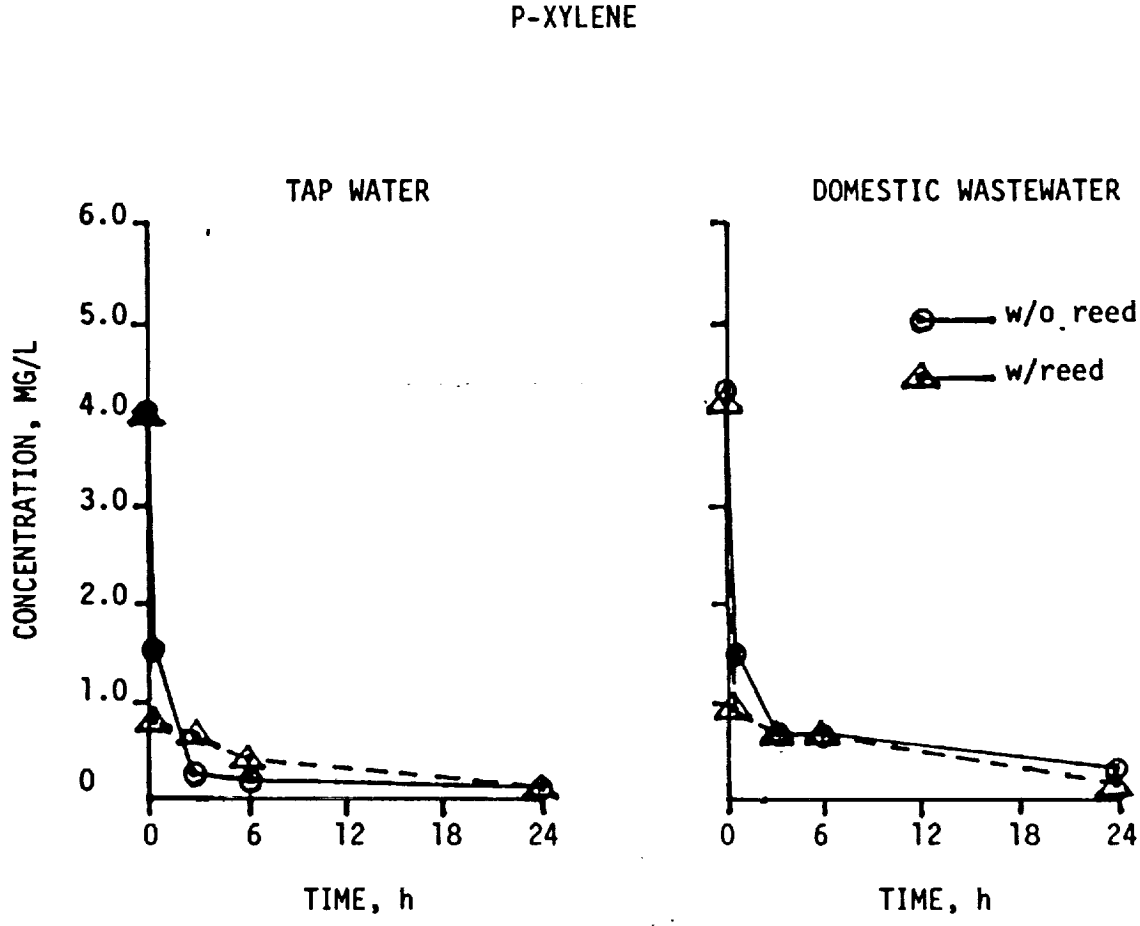

Figure 3. Removal of p-xylene from tap water and domestic wastewater as a function of filter exposure time.

Table 3. Mean pesticide concentrations in domestic wastewater as a function of exposure time in the filters.

Pesticide	System	No. Replicates	Concentration, mg/ℓ				
			0 h	<0.1 h	3 h	6 h	24 h
Lindane	w/o reed	8	5.600	1.910	1.050	0.776	0.767
	w/reed	8	5.691	0.881	0.453	0.452	0.440
Chlordane	w/o reed	8	6.762	2.883	1.255	0.995	0.343
	w/reed	8	6.521	0.443	0.404	0.398	0.139

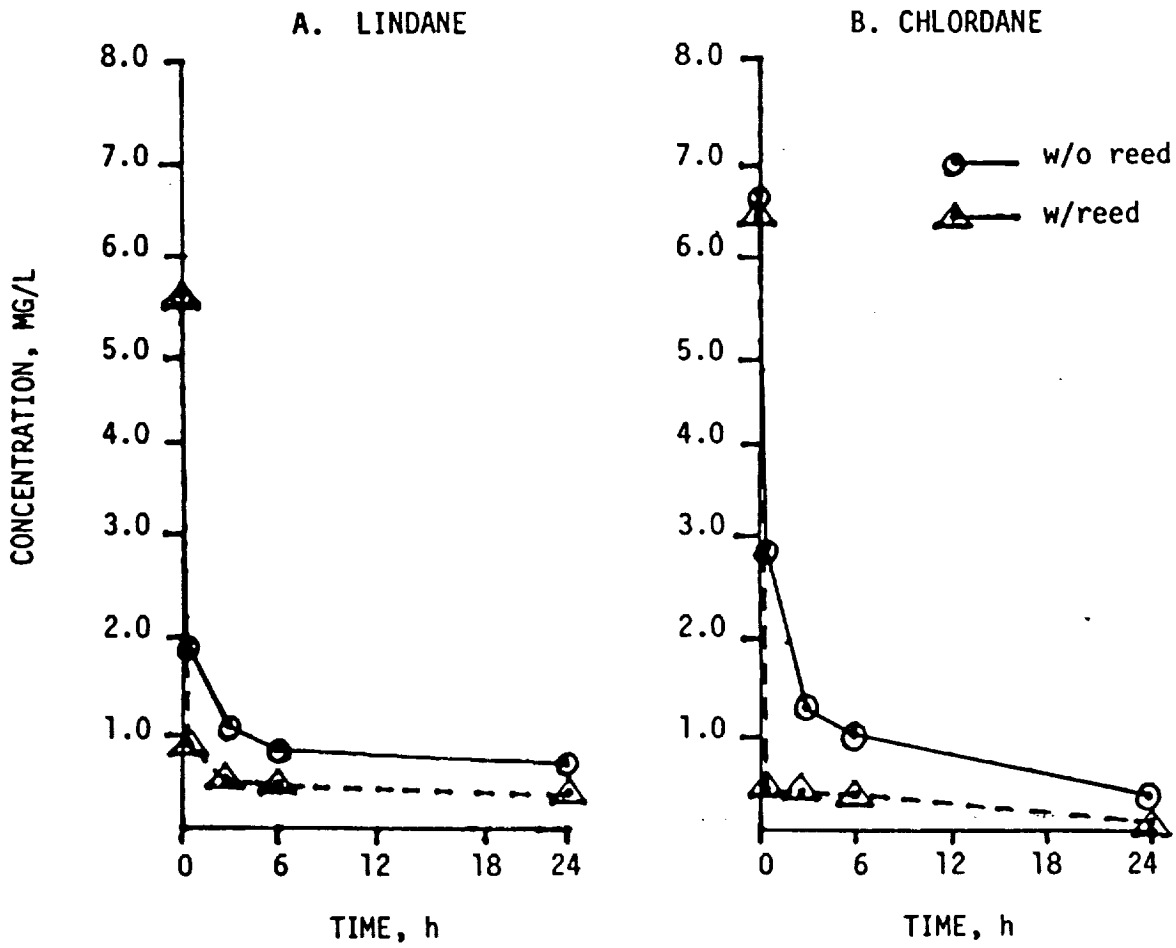

Figure 4. Removal of lindane and chlordane from domestic wastewater as a function of filter exposure time.